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TOTAL ECLIPSES.

TENNANT.

1868



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# TOTAL ECLIPSES,

AND

THE TOTAL ECLIPSE OF 18TH AUGUST, 1868.

BY

MAJOR J. F. TENNANT, R.E., F.R.A.S., F.M.S.



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1868.



## TOTAL ECLIPSES.

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DURING the present year there will be seen in India a total Eclipse of the Sun. This forthcoming phenomenon has excited the interest of Astronomers and Physicists in all parts of the world, and the Government of India has, on the representation of the Astronomer Royal (made on behalf of the Royal Astronomical Society), undertaken, in conjunction with the Imperial Treasury, to defray the cost of making observations of this phenomenon. The Royal Society has also made arrangements to avail itself of the skill of officers of the Great Trigonometrical Survey for the same purpose. I shall endeavour to explain why this has been done, and to give some account of the very rare phenomenon which has called forth so much attention.

It is known to all who are even slightly acquainted with Astronomy that an Eclipse of the Sun is caused by the interposition of the solid body of the Moon between the Sun and the spectator. The nature and amount of the Eclipse depend on the relative positions of the Sun, Moon, and Observer as referred to the Earth's centre. To predict an Eclipse at all, most of all to predict it accurately, requires that we should know what are the relative positions and sizes of these three bodies, and also their motions both in direction and amount. Whenever the line joining the centres of the Sun and Moon meets the Earth's surface, the Eclipse will be central at the point of intersection; and, as the position of this line is constantly changing in consequence of the motions of the bodies, the result is that the Eclipse will be central successively at all points in a curved line on the Earth's surface. If the diameter of the Moon, as seen at the place of observation on the central line, be apparently less than that of

the Sun, then a ring of the Sun's light will be seen round the Moon; such an Eclipse is called annular. If the apparent diameter of the Moon be greater than that of the Sun, then the latter body will be totally obscured, and the Eclipse will be total. These phenomena of annularity and totality will also be seen some little distance on either side of the central line; that is, at all points where the *apparent distance* of the centres is not greater than the *apparent difference* of the diameters. The duration of the greatest phase on the central line will depend mainly on the difference of the apparent diameters, and at any other point within the limits on the distance of the point from the central line.

The occurrence of Eclipses is one of the most delicate verifications of Astronomical Tables. Errors, such as any ordinary observer could detect in the times at which certain phases occur, would be produced by tabular errors so small that they would only be sensible otherwise to instruments of the greatest accuracy. Eclipses are carefully observed at all observatories where they are visible to make these verifications, and so great is the accuracy of our modern Tables, that whereas a change in the observer's position of half the diameter of our Earth (say 4,000 miles) would displace the Moon's centre by a space equal to about double its apparent diameter, we are able to assign within a mile or two the place where a given phase shall occur at a given time. Nay, we can assign these points nearly as accurately for thousands of years back. There are some Eclipses recorded by ancient writers of which the narratives have been carefully compared with modern Tables, and with the most satisfactory results. Of these perhaps the most remarkable is one related by Xenophon to have occurred while the Persians were besieging the Median garrison of a city called Larissa. The Astronomer Royal has shown that there was a total Eclipse of the Sun answering the description given, and that it was so total only over a very narrow belt of country, and only of course for a short time. It was total at the place now known as Nimrûd, and at no other which would have been near the Greeks.



We know then not only that Xenophon's narrative was correct in this matter, but we can assign a positive date to the occurrence, and we know with a certainty beyond what is to be got in any other way that the Nimrûd of to-day is the lost Larissa of Xenophon's time.

I have said above that the observation of Eclipses is one of the most delicate tests of Astronomical Tables, but great Eclipses occur very rarely, and our Instruments have been so much improved of late years, that we might almost dispense with Eclipse observation for the purpose of verifying or improving our Tables. Were that the only object, I should not have had given me, by the liberality of our Government, an opportunity of seeing a phenomenon which, those who have witnessed it declare, is glorious and astonishing beyond the power of words to express, and one never to be forgotten.

Close on the time predicted there is to be seen at a fore-known point on the Sun's limb a flattening ; this increases till it is clear that the curved limb of the Moon is overlapping that of the Sun. Gradually the Eclipse progresses ; the darkness increases ; the color of the light changes. It becomes lurid ; all nature seems to feel the occasion. Animals and birds are affected as much as reasoning men. The Astronomer who knows what is coming, who knows that when the hands of his watch reach a certain point, the Sun will be dark and the Moon will not show her light, feels the same anxiety. It is with the greatest difficulty he can keep his presence of mind, and not unfrequently those who go to make observations lose their chance ; then, carefully prepared projects vanish from their minds, they look on awe-struck, and are powerless to do aught but gaze. The visible portion of the Sun grows smaller, and the light seems to pale ; at last the edge of the shadow passes the place almost as though it were material, and the last trace of our familiar Sun is gone. Then we see a sight overpoweringly glorious. The sky is dark, except towards the horizon, and the Stars are seen as in deep twilight ; but where the Sun was, is the black surface of the Moon surrounded by

a corona, or glory, of light which appears often to vary in brightness, and have frequent bright coruscations darting from the Moon's edge. On this, and closely surrounding the Moon, are seen as it were flames or clouds of various tints of red and very bright. At last the Moon has passed the Sun, a slight gleam of light is seen outside its limb, and the strain is over—daylight has returned. Bird, beast, and man are relieved—the suspense is over. Now these flames and corona are only visible during total Eclipses of the Sun. Many efforts have been made to see them by artificially obscuring the Sun, but all without success. Men of science are therefore anxious that no opportunities should be lost of investigating their nature. In 1860 there was an Eclipse of the Sun, now of some celebrity. Spain (where it was total) was visited by many Astronomers from all parts of Europe. H. M. S., "Himalaya" was freighted with Astronomers and their instruments, who were by the orders of the Admiralty conveyed to Bilbao and Santander, and re-conveyed to England. Their researches left much to be learnt. As to the corona we do not know whether it is the heated, and therefore luminous, atmosphere of the Sun, or if it be merely a phenomenon of our own atmosphere. As to the flames (or prominences as they are now generally called), it is certain that they belong to the Sun, but what they are we do not know. They must be huge—far larger than any of the planets, and having a volume which is a sensible fraction of that of the Sun; but what are they? Do they shine by their own light? And if so, what is the substance from which that light proceeds? Or do they owe their brilliancy, which exceeds that of the Moon at full, to their power of reflecting the light of the Sun?

Such are the questions which now occupy the minds of Astronomers, and to these I have been deputed to endeavour to give answers. The occasion is singularly favorable. I need hardly say that the necessary observations require time. Now the total phase of an Eclipse lasts generally only three or four minutes at most, while the duration of the totality during the Eclipse, which I am to endeavour to observe, is unprecedented. That long known

in Scotland as the 'Black-hour' can alone have been near it. In India it will be from five minutes to five minutes and three quarters, and near the French settlement of Saigon it will be six minutes and three quarters. There is no record of such a duration of the total phase of an Eclipse, and it will be very many years before an opportunity so favorable of making the observations sought recurs. The attention of the Royal Astronomical Society having been called to the matter, it was warmly taken up by the Council, and urged on Government by the Astronomer Royal. The result has finally been, that I have been deputed to superintend a series of observations, of which the expense will be shared by the Imperial and Indian Governments, and to which the Royal Observatory at Greenwich and the Royal Astronomical Societies have contributed by the loan of Instruments. Nor have the Royal Society, which administers a Fund specially devoted by the Imperial Government to the promotion of science, been wanting. They too, mindful that a cloudy morning or even a few minutes of cloud on one part of the sky would be fatal to observation, have determined that the chance should be doubled, and have entrusted Lieutenant Herschel, R.E., (third in descent of a family of Astronomers and men of science,) with Instruments for some of the same purposes.

And now, perhaps, I may endeavour, in a general way, to describe the means at the disposal of Astronomers for solving these problems. I shall endeavour to answer as briefly and untechnically as possible the question how we are to obtain information as to the corona and prominences which appear to be beyond our reach.

Those who have any knowledge of the phenomena of light know that light which has fallen on a plane surface at certain angles, and been reflected by it, has undergone a peculiar modification. Unchanged in color, and possibly not much diminished in brilliancy, it has acquired new properties, and when examined by suitable apparatus shows bands, rings, crosses, &c., of darkness and color, according to circumstances, which could not have been seen in the light, while pursuing a straight course from the

radiant point. Light so modified is called polarized, for reasons with which I shall not trouble you, and if even the reflection be not at the precise polarizing angle, still more or less polarization takes place, and is recognized by the presence of its peculiar phenomena. Now if the corona be the self-luminous atmosphere of the Sun, its light will not be polarized. If it be either an atmosphere about the Sun shining by light originating in the luminous photosphere of the Sun, or a phenomenon of our own atmosphere, we may expect to see the phenomena of Polarization, but they will differ in the two cases.

Then we have another means of examining objects at a distance, not only as to their source of light, but, strange to say, as to the very chemical constitution of that source. You all know that if a ray of white or sunlight passes through a triangular prism of glass, it becomes spread out and tinged with color. One end of the spreading or spectrum as it is called becomes blue, the other red ; while between lie green and yellow tints. Wollaston and Fraunhofer, by using prisms of very fine glass, and observing this spectrum with a telescope, found that it was crossed with numerous dark lines, and these lines, by enabling opticians to identify particular parts of the spectrum, have aided very much in perfecting the Achromatic Telescope. Then it was found that light emanating from different substances, when ignited, gave different spectra, and finally all the phenomena were united under one theory, which has led to the remarkable results of Bunsen, Kirchhoff, Huggins, and Miller. It is now known that the light emanating from an incandescent solid or liquid gives a continuous spectrum without lines of any sort. From an incandescent gas the light gives a spectrum consisting of isolated bright lines with some modifications, depending on the temperature to which the gas is raised ; but if an incandescent solid be surrounded by gas (whose temperature does not allow it to produce light as bright as that from the solid) the continuous spectrum due to the solid is broken ; the gas stops precisely those rays which it is itself capable of producing. Each gas of a mixture produces its own system of

dark lines, and the general result is a spectrum more or less such as that of sunlight. By carefully examining the lines in the Solar Spectrum, and comparing them with the luminous lines from various gases and vapors, Kirchhoff has shown that the Sun consists of a luminous nucleus, surrounded by an atmosphere less luminous, consisting of mixed vapors.

In this atmosphere he has proved the existence, beyond all doubt, of several known elements. One particular group of lines he has recognized as being produced by the vapor of iron with what amounts to certainty. Now iron can only exist in vapor at a very high temperature, especially under such a pressure as must exist at the surface of the Sun, and this vapor must be incandescent and luminous. So great, however, is the heat of the solar nucleus, and the intensity of the light emanating from it, that this luminous vapor produces dark lines only. When the light of the nucleus is absent, as in a total Eclipse, we may expect to see the light from the luminous atmosphere, and to obtain further information as to its nature. We already know that several of the stars (bodies so distant that the light we see some of them by left them before the generally assigned date of the Earth's creation) have atmospheres containing some of the same chemical elements as the Earth itself and the Sun. We know that some of the Comets, at all events, are filmy gas so heated as to become luminous, and their faint light and very small mass as compared with their volume become intelligible, and so too some of the nebulae are mere gas heated to ignition, and now we seek to take advantage of the Eclipse and pry nearer home into the atmosphere of our Sun, and ascertain further of what it is made. This is the newest, and will be the most important, of the objects of our research.

In the total Eclipse of July, 1860, Mr. De la Rue succeeded in obtaining two Photographs of the corona and prominences surrounding the Moon when the Sun was entirely eclipsed, and some were obtained by Father Secchi of Rome. These have been most valuable. It was always a matter of doubt whether the prominences of which I have spoken belonged to the Moon

or to the Sun. They had been seen by many Astronomers, but (so exciting are the circumstances of a total Eclipse) their opinions differed. Some were confident that they saw them covered on one side and opened on the other, as the Moon moved over them ; while others as confidently asserted that they were not so affected. The determination of this point was the most important object of research in 1860. From various causes these two photographs of Mr. De la Rue's are the most important, though not the sole evidence. They show, beyond all doubt, that these prominences or flames are fixed relatively to the Sun, and that they are covered on one side and uncovered on the other by the Moon as it moves. But they have told more. They show that one or two of the prominences are not attached to the Sun, but are apparently clouds floating in its atmosphere, and, moreover, it seems probable that they are (some of them, at all events) self-luminous. Photographers know that the portion of the spectrum which impresses itself on a sensitive plate is not identical with that which is visible. We see rays which have no chemical effect, and the plate recognizes rays which we cannot see. Now, though sunlight thus contains rays which we cannot see, yet, so far as we know, no substance reflects these alone. But the comparison of the photographed prominences with other pictures made with great care from an eye-view, has led to the conviction that there were chemically depicted on the sensitive plate prominences conspicuous from their size which were not seen. All this rests mainly on Mr. De la Rue's two photographs. The sensitive plates, free from the agitation under which men were observing, have rendered a great service to astronomy, by placing beyond all doubt what were facts on July 18th, 1860. But we do not yet know if these facts are general, and I am to endeavour to repeat Mr. De la Rue's experiment with apparatus more especially adapted to the purpose.

In order to obtain these results, I have been furnished with means and assistance, but we have by no means exhausted all that is wanted. I shall be happy to furnish a note of objects for

observation to any who will be on or near the central line, and who are willing to aid the cause in which I am engaged.

Sketches carefully made at the Telescope of the prominences at different points of the line will be one of the most important. I should recommend any one to take only one Quadrant of the Moon's limb, and to make, if possible, one sketch of all he sees on it, and verify it. If he can persuade a friend to make another, perfectly independent of the same Quadrant, it will be valuable. Each will probably contain what the other does not, but however they may at first differ apparently, if carefully made, both will have their peculiarities explained by the photographs which I hope to get. Notes on the Stars visible, and especially the smallest visible, will give an idea of the darkness. There are several matters connected with the peculiarities of the illumination at the totality well worthy of attentive examination. What a man had best do depends on his means and habits of observing. Isolated and unconfirmed results from the most practised observers must under such circumstances be subject to doubt, but the careful record of what one of less experience sees may give the needful confirmation, and I shall hope to have communications of such to be used as I think best.

In conclusion, I would say to every one, if you can, go and try to see the Eclipse. If you make no observations, you will, if you are favored with a clear sky, see a sight such as will richly repay you, and such as you may never again have the chance of seeing.

J. F. TENNANT, MAJOR, R. E.

*Postscript to Major Tennant's paper.*

I have described in this paper the sudden appearance of corona and flames as they are usually seen. In July, 1860, the Astronomer Royal observing in Spain saw a prominence before the last of the Sun was gone, but it was only a few seconds before, and in a telescope. He says (*Ast. Soc. Month. Not.*, Vol. XXI, page 9)—“When, from the narrowness of the sun's lune, I judged that the totality would occur in ten or fifteen seconds,

I withdrew the graduated colored glass. To my infinite astonishment, while the white sun was still shining brilliantly, I saw in great splendour two red prominences (possibly there were more than two visible) and one double floating red cloud. But before the white disc had disappeared the white corona formed round the Moon, I think, all at once, and the Moon was seen complete with dazzling sun, brilliant corona, and brilliant prominences. The intensity of the light of the corona and prominences was not much increased at the total disappearance of the Sun."

We might perhaps have guessed that, suitably observed, these prominences might have been sooner seen, but one could hardly suppose that they should be seen a quarter of an hour on either side of the greatest phase. Such, however, would be the legitimate conclusion from observations by Ensign Kiha, of the Austrian Navy, on the Annular Eclipse of March 6th, 1867, in Dalmatia. This is so important that I have endeavoured to translate the account as given in the *Astronomische Nachrichten* by Dr. Edmund Weiss of Vienna, who directed the observations for Astronomical purposes. Ensign Kiha was placed about two and a half geographical miles North-West from Ragusa on the computed limit of annularity of the Eclipse, and was observing with a Telescope by Plössel of two inches aperture, and a magnifying power of 40 times. The observation he makes as to the corona is not new. In every large partial Eclipse the form of the Moon has been seen relieved on the sky far beyond the Sun's limb. It has been doubted if this brightness be the real corona, and it is probable Ensign Kiha never saw that phenomenon in its brilliancy. It is difficult to conceive that the appearance described by Mr. Airy is merely a sudden increase of apparent brilliancy in a previously seen object, and still more to understand why, if it were so, it should take place while the Sun's light is decreasing continuously. But the most remarkable statement is as to the visibility of the protuberances. I was at first disposed to think that, as, in narrating the means used to observe, no mention was made as to a dark glass, Ensign Kiha might have found it practicable to dispense with one; but it is stated further on that he used a glass of



cobalt blue .If the corona were really seen, then the prominences, which are universally considered brighter, might have been seen ; but they never have been so in the numerous Eclipses of all sorts, annular, total, and partial, which have been carefully watched by skilled observers. The cusps have received special notice, having been measured in various ways. Though the Astronomer Royal and Mr. Baily were the first, I believe, to give prominence to the appearance of protuberances, yet they were seen before ; but this observation of Ensign Kiha's is unique. We may expect, if there be a similarly visible prominence next August, that it will be seen near the cusps between the latitudes of  $22^{\circ} 30'$  on the North, and  $10^{\circ}$  on the South, in India ; also at Rangoon, Moulmein, &c., and the Andaman Islands. My attention was called to this observation by the Annual Council Report of the Royal Astronomical Society, it having been originally passed over by me as not bearing on total Eclipses, when I had not much time to attend to anything else.

*Translation of an Extract from the Account (by Dr. EDMUND WEISS of VIENNA) of the Annular Eclipse of the Sun on March 6th, 1867.*

(“Astronomische Nachrichten,” Vol. 69, page 228.)

Besides, this Ensign of a Ship of the Line, Kiha, saw still twenty-eight minutes after the annularity traces of the corona in a dull light which surrounded the Moon's limb far beyond the disc of the Sun, and almost all the other phenomena which till now we have perceived at total Eclipses. By far the most important of these is that of a protuberance of brownish yellow, in appearance like a small flame with darker streaks of the same color in the direction of its length, which remained in position angle of  $153^{\circ}$  at the Sun's centre, measured from North by East, and carried over the Equator (nearly perpendicular to the apparent path of the Moon). Ensign Kiha noticed this protuberance near the point of the upper (Southern) cusp of the Sun 14.4 minutes before the formation of the Ring, and could follow it till 14.7 minutes after





the same moment. He saw it, therefore, with interruptions indeed from passing clouds, during 29.1 minutes, and moreover at the uncovered part of the Sun's limb. For the detail of this interesting observation I must refer to the Memoirs of the Imperial Academy, which contain the original account, with two drawings of the protuberance by Ensign Kiha. Both these observations stand alone in their kind, and are so far of unmistakable value, as they throw entirely a new light on the visibility of these appearances. According to the usual reckoning, the Eclipse had a magnitude of 10.1 digits when Ensign Kiha first saw the protuberance, and had returned to 10 digits when he last saw it. Besides which it must be noted that the protuberance did not vanish from Kiha's eyes on account of its faintness, but from a clouding over, and that it must have been a somewhat conspicuous object at its first appearance, since it was also remarked by his companions, when he called their attention to it, though they observed only with very small telescopes.

This observation also teaches us that the visibility of protuberances is not confined to the zone of the totality or annularity and its immediate neighbourhood, but may sometimes, under favorable circumstances, extend to a large partial Eclipse. For instance, the protuberance seen at Barsecienne could have been visible over a zone extending from Prague to Athens. One would do well then to look for these protuberances at every considerable partial Eclipse during its greatest phase. In order to make the neighbourhood of the cusps more favorable for this, it would be desirable to remove the other parts of the Sun as much as possible from the field of the telescope, and to use as pale a dark glass as possible. It is besides advisable to use dark glasses of colors differing from each other, since the color of the protuberances is very variable, and they would stand out better from the background if seen sometimes through one, sometimes through another. Generally, blue glasses might render the best service, as indeed Kiha at first saw the protuberance through a pale cobalt glass.











